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(54) Generation of intense transient magnetic fields

(57) In a laser system, the return current of a laser generated plasma is conducted near a target 11 to subject that target to a magnetic field. The target 11 may be either a small non-fusion object for testing under the magnetic field or a laser-fusion pellet. In the laser-fusion embodiment, the laser-fusion pellet 11 is irradiated during the return current flow and the intense transient magnetic field is used to control the hot electrons thereof to hinder them from striking and heating the core of the irradiated laser-fusion pellet. An emitter 17, e.g. a microballoon of glass, metal or plastics, is subjected to a laser pulse to generate the plasma from which the return current flows into a wire cage 13 or a coil and then to earth.

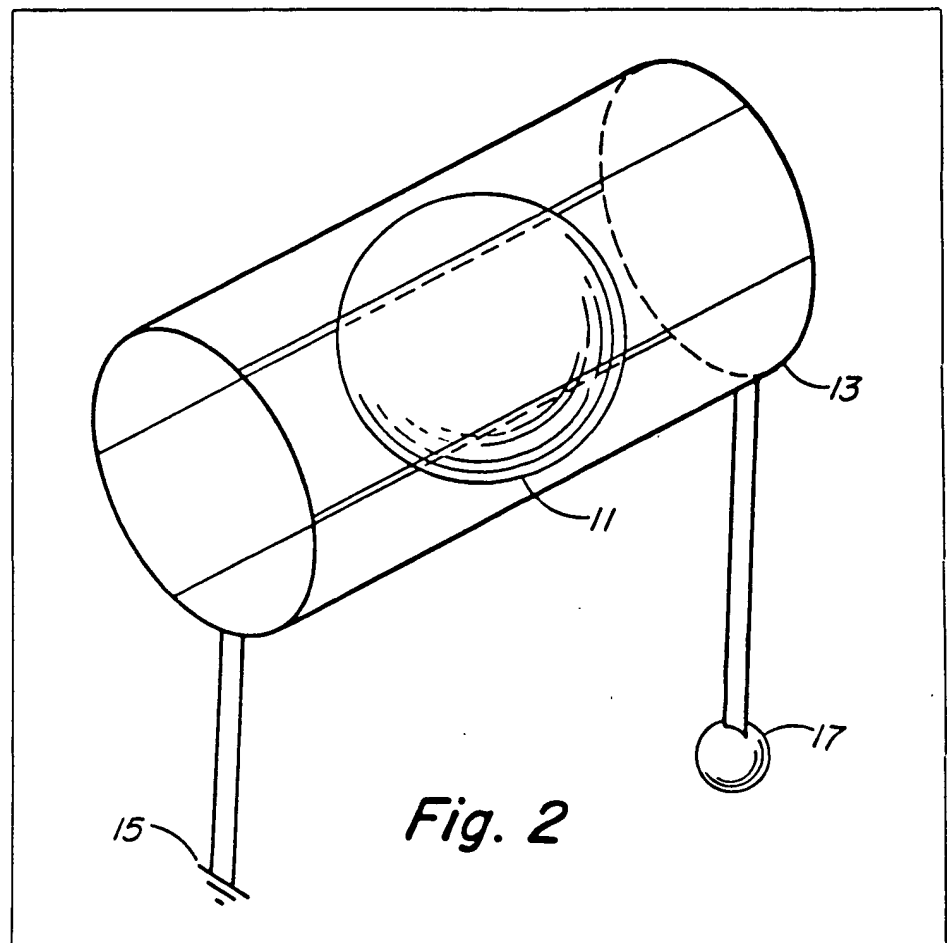
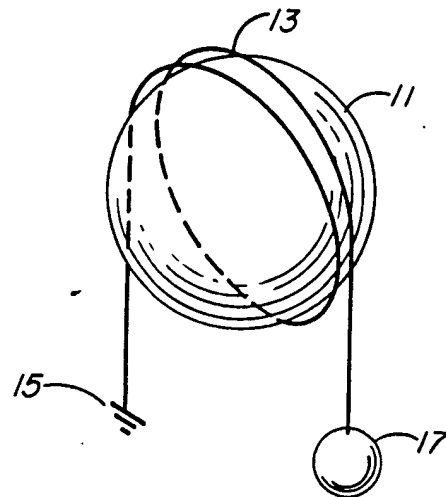
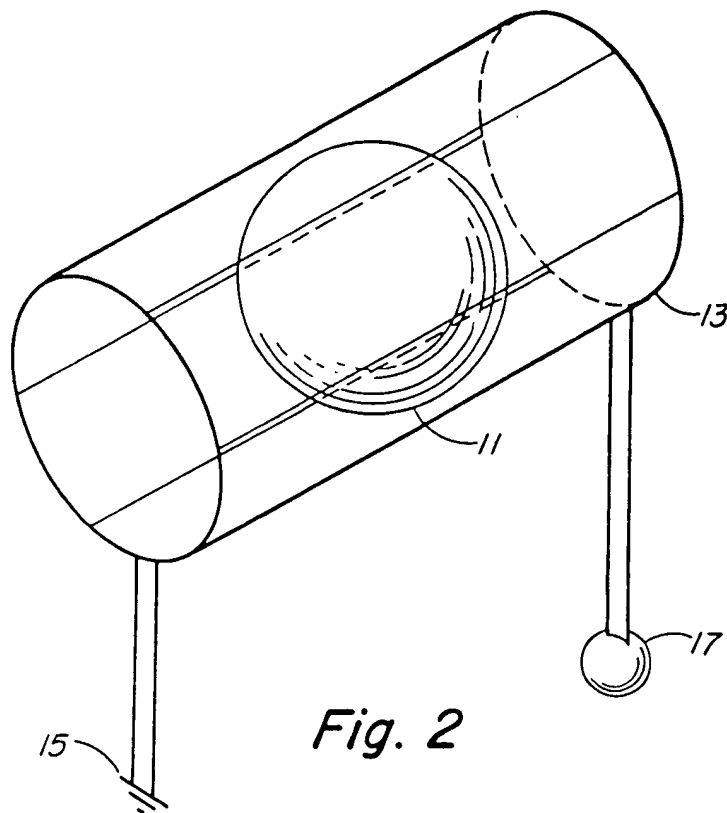


Fig. 2

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*Fig. 1**Fig. 2*

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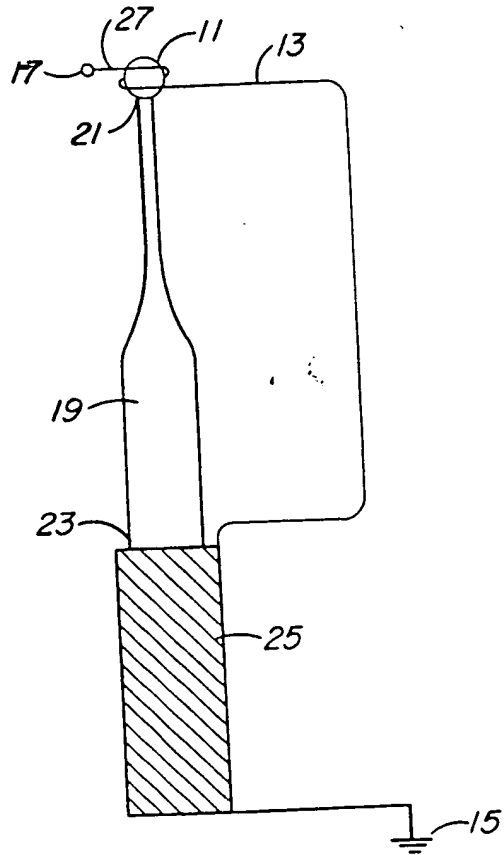


Fig. 3

SPECIFICATION

Intense transient magnetic field generation by laser-plasma

- 5 The present invention relates generally to generation of intense transient magnetic fields and more particularly to the generation of an intense transient magnetic field through a laser-plasma method and apparatus.

- 10 One field in which such a generation of an intense transient magnetic field would be most useful is the field of laser-initiated thermonuclear fusion power generation. One technique proposed to generate electrical power from a controlled thermonuclear event involves injecting a small deuterium-tritium pellet into a vacuum chamber and triggering a fusion reaction by "driving" the deuterium and tritium ions together with the energy supplied by laser beams to produce a helium ion and a neutron. Since the helium ion and neutron have slightly less mass than the deuterium and tritium ions a small amount of mass than the deuterium and tritium ions a small amount of mass is converted into energy in accordance with the famous Einstein equation $E = mc^2$ where E equals the energy produced, m equals the mass converted, and c equals the speed of light.

- 30 Absorption of the laser pulse quickly heats the outer region of the pellet to form an ionized gas or plasma that expands outward (blows off) rapidly. The recoil impulse from the very rapid blowing off of the outer pellet layer compresses the pellet core in the same way that the impulse from a rocket's exhaust pushes the rocket forward, or a rifle shot recoil pushes the rifle against one's shoulder. Theory predicts that the center of the pellet core will be compressed to superdensities, one to ten thousand times the normal solid density, or about ten times the density of the center of the sun (about one hundred times as dense as lead). Such pellet core densities are important because they greatly increase the likelihood that energetic deuterium and tritium ions will collide with one another. Also, they enable still unfused deuterium and tritium ions to recapture, or share, some of the energy of a fusion product helium particle before the high-velocity helium particle can escape the core region. This is analogous to one fast moving billiard ball striking and giving energy of motion to others. This energy sharing with unburned fuel gives rise to so-called "bootstrap" heating that further increases the reaction rate. Achievement of core compression is crucial to the laser fusion process.

- 60 In practice there are forces which oppose or hinder core compression. One problem just recently being recognized and studied is the effect of energetic or hot electrons generated in the pellet surface area plasma. The hot electrons produced move rapidly around and

- penetrate the pellet core causing heating thereof which makes core compression more difficult and thus for a given laser energy less compression results and final energy gain is reduced. The problems caused by hot electrons and the need to control same are discussed by R. B. Spielman et al., Physical Review Letters, Vol. 46, No. 13, p. 821 (30 March 1981). The measurement of a large return current in a laser-produced positively charged plasma is detailed by R. F. Benjamin et al., Physical Review Letters, Vol. 42, No. 14, p. 890 (2 April 1979).

- It is therefore an object of the present invention to control the hot electrons of a laser produced plasma to reduce pellet core penetration thereby.

- It is another object of the present invention to control the hot electrons of a laser produced plasma by the generation of an intense transient magnetic field.

- It is still another object of the present invention to generate an intense transient magnetic field useful in controlling the hot electrons of a laser produced plasma and further useful in other areas such as in experimental research concerned with the response of biological cells, organisms and other items to magnetic stimuli.

- 95 In accordance with the present invention a first laser produced plasma is initiated purposely to generate hot electrons and a positively charged plasma which is provided a low impedance path to ground to create an intense but very transient magnetic field via the high return current mechanism of the positively charged plasma. In one embodiment of the invention an object such as a biological cell or the like is confined within or near the provided low impedance path and is therefore subjected to the intense transient magnetic field. In another embodiment of the invention a fusion pellet is confined within or near the provided low impedance path and is laser irradiated shortly after the first laser produced plasma is initiated and during the period of the intense magnetic field whereby the hot electrons of the fusion pellet plasma are confined to extremely tight orbits and are controlled and hindered from penetrating the core region of the fusion pellet.

- An advantage of the present invention is that hot electrons of laser produced plasma are controlled by an earlier laser produced event thus the laser equipment needed and functioning to produce the fusion plasma can also be employed to produce the earlier hot electron controlling event.

- Another advantage of the present invention is that an extremely intense and transient magnetic field is produced for organic and inorganic experimental purposes.

- Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in

part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate an embodiment of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

Figure 1 illustrates a target surrounded by a coil attached to an emitter at one end and grounded at the other;

Figure 2 illustrates a target surrounded by a cylindrical cage attached to an emitter at one end and grounded at the other; and

Figure 3 details a configuration which surrounds a target with a coil in accord with embodiment of the invention shown in Fig. 1.

In accord with the present invention, a target 11 is secured within an intense transient magnetic field producing target assembly 13 connected to ground 15 at one end and to an emitter 17 at the other, see Fig. 1. When placed within an evacuated cavity and irradiated by an intense laser beam pulse, the emitter 17 is transformed into a highly charged positive plasma causing an intense return current to flow between the ground 15 and the emitter 17 through the target assembly 13 thereby subjecting the target 11 to an intense transient magnetic field.

The target assembly 13 formed as a helix or coil as shown in Fig. 1 subjects the target 11 to longitudinal magnetic field. Alternatively, the target assembly 13 may be formed as a cage to subject the target 11 to an azimuthal magnetic field, see Fig. 2. It is of importance to keep the target assembly 13 of low inductance and low resistance in order to generate the desired intense transient magnetic field.

The emitter 17 is preferably a microballoon of glass, plastic, metal, or any combination thereof. The emitter 17 is utilized to create a positive plasma when irradiated by a laser beam pulse of about 10^{15} watts/cm² or greater. With the hot electrons driven from the emitter 17 by the laser pulse, the high positive potential remaining causes an intense but transient current to flow through the target assembly 13 to ground 15, see Figs. 1 and 2. A suitable emitter is a glass microballoon of approximately 500 micrometers diameter.

Studies such as detailed by R. F. Benjamin et al., Physical Review Letters, Vol. 42, No. 14, p. 890 (2 April 1979) demonstrate that irradiated emitters can generate plasma potentials in the order of 180 kilovolts lasting for periods in the order of a nanosecond or more. Under such conditions intense transient magnetic fields on the order of a 100 or more

kilogauss can be generated depending upon the resistance and reactance of the return current path.

The target 11 is a small object on the order of 1 millimeter diameter. The target 11 may be organic, inorganic, metallic, non-metallic, or otherwise. In one application of the invention, the target 11 is a fusion-fuel containing pellet. These pellets are usually sub-millimeter-diameter hollow spheres of glass or metal (called microballoons) filled with a high-pressure DT gas and frequently coated with additional layers, or surrounded by concentric shells of metal and/or plastic to optimize the interaction of the target 11 with a laser beam.

When the present invention is used in laser fusion experiments or power generation, a short duration of about or less than a nanosecond before a main laser beam strikes the target 11, an auxiliary laser beam impinges on the emitter 17. The above described resultant "return current" creates a strong magnetic field near the target 11 at the instant the target 11 is irradiated. The strong magnetic field traps the hot electrons from the target 11 and keeps them in small orbits preventing them from heating the fuel within the target 11 and causing their energy to be deposited in the region exterior to the fuel containing core.

The target assembly 13 may be sized and located as desired. For example, the target assembly 13 may be exterior to the absorption region (i.e., the volume surrounding the target 11 where the main laser beam irradiation is absorbed). With the target assembly 13 fashioned as a cylindrical cage (see Fig. 2) the free electrons from the target 11 are trapped in small orbits as above described. Alternatively, the target assembly 13 may be located between the laser absorption region and the target 11 to magnetically shield the fuel of the target 11 from hot (or "energetic") electrons. Other options exist such as fashioning the target assembly 13 as a coil or helix to create a longitudinal magnetic field, see Fig. 1.

The actual physical fabrication of the subject invention is readily accomplished by those skilled in the art, see Fig. 3. A round glass rod 19 preferably about 4 cm in length and 2 mm in diameter is pulled to a tip 21 which is ground to 125 μ m diameter. The thick end 23 of the rod 19 is glued or otherwise secured to a metal base 25 while the tip 21 is likewise glued to the target 11 which may be a 1 mm aluminum ball or like sized DT fuel pellet. The target assembly 13 being a 255 μ m diameter copper wire is soldered to the metal base 25 and coiled around the target 11. The emitter 17 being preferably a 500 μ m glass microballoon is then glued to the target end 27 of the target assembly 13. To provide proper operation, the metal base 25 is connected to ground 15.

The present invention requires a high power laser facility. Such facilities are available at the Los Alamos National Laboratory and at numerous other laboratories, institutions and universities. An intense laser beam of about or greater than 10^{15} watts/cm² irradiance is preferable to generate the electromagnetic field necessary to accelerate electrons to velocities that enable them to escape the plasma and thereby create a positive potential at the plasma. A carbon-dioxide laser is preferred because it generates energetic electrons more efficiently than other commonly available lasers.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiment was chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

CLAIMS

1. An intense transient magnetic field producing apparatus for use with a high powered laser, said apparatus comprising:

emitter means for emitting hot electrons and creating a positively charged plasma when irradiated by the high powered laser;

target means for subjection to an intense transient magnetic field; and

grounding means connected to said emitter means and positioned near said target means, said grounding means for providing a return current path to ground for said positively charged plasma created by said emitter means whereby an intense transient magnetic field is created near said target means when said emitter means is irradiated by the high powered laser.

2. The apparatus according to claim 1 wherein said return current path provided by said grounding means includes a portion fashioned as a coil around said target means.

3. The apparatus according to claim 1 where said return current path provided by said grounding means includes a portion fashioned as a cylindrical cage around said target means.

4. The apparatus according to claim 1 wherein said emitter means is a microballoon.

5. The apparatus according to claim 4 wherein said microballoon is a glass microballoon.

6. An intense transient magnetic field pro-

ducing apparatus for use with a laser fusion system having a high powered laser, said apparatus comprising:

emitter means for emitting hot electrons and creating a positively charged plasma when irradiated by the high powered laser; a laser-fusion pellet for subjection to an intense transient magnetic field; and grounding means connected to said emitter means and positioned near said laser-fusion pellet, said grounding means for providing a return current path to ground for said positively charged plasma created by said emitter means whereby an intense transient magnetic field is created near said laser-fusion pellet when said emitter means is irradiated by the high powered laser.

7. The apparatus according to claim 6 wherein said return current path provided by said grounding means includes a portion fashioned as a coil around said laser-fusion pellet.

8. The apparatus according to claim 6 where said return current path provided by said grounding means includes a portion fashioned as a cylindrical cage around said laser-fusion pellet.

9. The apparatus according to claim 6 wherein said emitter means is a microballoon.

10. The apparatus according to claim 9 wherein said microballoon is a glass microballoon.

11. The apparatus according to claim 7 wherein said laser-fusion pellet has a defined absorption region external to said laser-fusion pellet and said portion of said grounding means fashioned as a coil surrounds said laser-fusion pellet within said defined absorption region.

12. The apparatus according to claim 7 wherein said laser-fusion pellet has a defined absorption region external to said laser-fusion pellet and said portion of said grounding means fashioned as a coil surrounds said defined absorption region.

13. The apparatus according to claim 8 wherein said laser-fusion pellet has a defined absorption region external to said laser-fusion pellet and said portion of said grounding means fashioned as a cylindrical cage surrounds said laser-fusion pellet within said defined absorption region.

14. The apparatus according to claim 8 wherein said laser-fusion pellet has a defined absorption region external to said laser-fusion pellet and said portion of said grounding means fashioned as a cylindrical cage surrounds said defined absorption region.

15. A method of subjecting a plasma to an intense transient magnetic field comprising the steps of:

providing a return current path;

generating an intense transient return current flow upon said return current path; and

creating a plasma near said return current path during said intense transient return cur-

rent flow there upon whereby said plasma is subjected to the magnetic field thereof.

16. The method of claim 15 wherein said return current path includes a portion fashioned as a coil and said plasma is created therein.

17. The method of claim 15 wherein said return current path includes a portion fashioned as a cylindrical cage and said plasma is created therein.

18. In a laser system, a method of subjecting an object to an intense transient magnetic field, said method comprising the steps of:

15 providing a grounded return current path having an ungrounded end;
securing an emitter on said ungrounded end of said grounded return current path, said emitter fashioned so as to create a highly
20 charged plasma when irradiated by a laser;
placing said object near to said grounded return current path; and
laser irradiating said emitter thereby creating said highly charged plasma and causing
25 an intense transient return current flow on said grounded return current path whereby said object is subjected to the magnetic field thereof.

19. The method of claim 18 wherein said grounded return current path includes a portion fashioned as a coil and said object is placed therein.

20. The method of claim 18 wherein said grounded return current path includes a portion fashioned as a cylindrical cage and said object is placed therein.

21. In a laser-fusion system, a method of subjecting the plasma of a laser irradiated laser-fusion pellet to an intense transient magnetic field, said method comprising the steps of:

40 providing a grounded return current path having an ungrounded end;
securing an emitter on said ungrounded
45 end of said grounded return current path, said emitter fashioned so as to create a highly charged plasma when irradiated by a laser;
placing a laser-fusion pellet near to said grounded return current path, said laser-fusion
50 pellet fashioned so as to create a plasma when irradiated by a laser;
laser irradiating said emitter thereby creating said highly charged plasma and causing an intense transient return current flow on
55 said grounded return current path; and
laser irradiating said laser-fusion pellet during said intense transient return current flow on said grounded return current path thereby subjected said plasma of said laser-fusion pellet to the magnetic field of said intense transient return current flow.

22. The method of claim 21 wherein said grounded return current path includes a portion fashioned as a coil and said laser-fusion
65 pellet is placed therein.

23. The method of claim 21 wherein said grounded return current path includes a portion fashioned as a cylindrical cage and said laser-fusion pellet is placed therein.

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